AMAZONIANA	VII	4	465 – 477	Kiel, Januar 1983

A comparative study of the growth of the postlarval and juvenile Pescadas *Plagioscion squamosissimus* (HECKEL) and *Plagioscion monti* (SOARES) in a white water lake of the Central Amazon

by

Heino O. Worthmann

Hydrobiological Research Institute, University of Istanbul, Türkiye

Introduction

Although the Pescada (*Plagioscion* spp.) is not one of the most important fish of the Central Amazon, it has a high commercial value as a consume fish on the Manaus fish market. Approximately 300 t are landed here annually.

Until now, there has been little known about the biology of the Pescadas – one species, *P. monti*, was first described by SOARES in 1978. The only recent publications dealing with Pescadas are a revision of the Sciaenidae family from SOARES (1978) and a study on the growth of *P. squamosissimus* in tanks from NOMURA (1976). PEIXOTO (1953) observed the growth of postlarval and juvenile fish under artificial conditions in tanks and SILVA and MENEZES (1950) gave a rough summary on the diet of *P. squamosissimus.*

So far, it has been difficult to determine the age of tropical fish as they do not have any seasonal rings on their otoliths or scales as do fish from temperate zones. A very precise age determination was first possible when PANELLA (1971) found daily rings on otoliths.

As the von BERTALANFFY growth curve only describes the growth of juvenile fish insufficiently, it was important to determine their actual growth under natural conditions.

For this reason, the growth of both species of juvenile fish (between 0.4 and 15 cm length) was studied in Lago do Janauacà, a white water lake on the right bank of the Rio Solimões, approximately 60 km upstream from Manaus.

Material and Methods

The age of 370 *P. monti* and 280 *P. squamosissimus* (0.4 - 15 cm standard length) were determined in order to calculate the growth rate. 210 *P. monti* came from catches with a narrow-meshed (5 mm) seine on 11.10.78 and 182 *P. squamosissimus* with a ring-trawl (500 μm) on 17.11.79. 160 *P. monti* and 98 *P. squamosissimus* were caught during 1978. Their standard length was measured to the nearest mm and their weight determined to the nearest mg. Due to the large number of fish in the seine and ring-trawl catches, these were conserved in 70 % alcohol making it necessary to recalculate the weights and lengths of the fresh fish. The conversion formula for the length of *P. monti* is:

$$L_F = 1.0207\ L_K + 0.0438 \qquad r^2 = 0.998 \qquad n = 157$$

the weight:

$$G_F = 1.4311\ G_K - 0.0088 \qquad r^2 = 0.998 \qquad n = 157$$

The confidence interval of the regression coefficients in the 95 % range was $\pm$ 0.0099 for the length and $\pm$ 0.0230 for the weight.

The length of fresh *P. squamosissimus* can be calculated as follows:

$$L_F = 1.0350\ L_K + 0.0211 \qquad r^2 = 0.999 \qquad n = 136$$

and the fresh weight:

$$G_F = 1.3943\ G_K + 0.0041 \qquad r^2 = 0.996 \qquad n = 136$$

The 95 % confidence interval was $\pm$ 0.0051 for the length and $\pm$ 0.0092 for the weight. The age of the fish was determined by reading the daily rings on otoliths. The asteriscus was used for fish less than 2.5 cm in length, the sagitta for fish greater than 2.5 cm in length. The possibility of using two otoliths, for age determination and their simultaneous formation in the labyrinth was discussed by WORTHMANN (1980).

The asteriscs were fixed on a microscopic slide with EUPARAL and read immediately with a stereomicroscope and magnification of 1000 x. After their removal, the sagittas were embedded in polyester and cut medianlongitudinally with a saw developed by RAUCK (1976). These sections were adhered to microscopic slides and ground to a suitable thickness. The daily rings were counted using a magnification of 1000. The standard lengths from fish $<$ 50 mm were grouped in mm classes; the lengths of fish $>$ 5 cm in cm classes. The weights of fish were grouped in 5 g classes. 10 otoliths were read per length group as far as it was possible.

Results and Discussion

As the cuts from the sagittas were not always made through the center of the otoliths, the ages were summarized in 10-day groups from fish 0.4 - 15 cm in length in order to calculate the growth curves. The length-age data are shown in Tab. 1 and 2.

For both species, the length-age relationship for the relatively short time interval of 1 year, could be represented by a linear regression; the weight-age relationship by a exponential function:

P. monti

$$L_t = 0.0707\ T + 0.1263 \qquad r^2 = 0.9878 \qquad n = 370$$

$$W_t = 7.1656 \cdot 10^{-5}\ T^{2.5552} \qquad r^2 = 0.9713 \qquad n = 370$$

Tab. 1: The age of *P. monti* in days per cm length group

length in cm \ age in days	0 - 10	11 - 20	21 - 30	31 - 40	41 - 50	51 - 60	61 - 70	71 - 80	81 - 90	91 - 100	101 - 110	111 - 120	121 - 130	131 - 140	141 - 150	151 - 160	161 - 170	171 - 180	181 - 190	191 - 200	201 - 210	211 - 220	221 - 230	231 - 240	241 - 250	
1	8																									8
2	6	44	42	3																						95
3			7	33	12	2																				54
4				2	26	16	8	1																		53
5					5	17	23	8																		53
6							11	7	2																	20
7								1	2	5	1															9
8									2	3	2	2														9
9											1	4	4	1												10
10												2	6		1	1										10
11														1	1	2	4	1	1							10
12														1	1	2	2	1	2							9
13																1		3	3		1	1				9
14																	1	1	2	5	1	2	1			13
15																		1	1	1	2	1	1		1	8
n	14	44	49	38	43	35	42	17	6	8	4	8	10	3	3	6	7	7	9	6	4	4	2		1	370

Tab. 2: Length – age key of *Plagioscion squamosissimus*

Length \ days	1-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	91-100	101-110	111-120	121-130	131-140	141-150	151-160	161-170	171-180	181-190	191-200	201-210	211-220	221-230	231-240	241-250	251-260	261-270	271-280	281-290	291-300	301-310
0	23	25																													
1		95	21																												
2				12	1																										
3						1																									
4							1	1																							
5									1	6	3	2																			
6										1	2	1	4	3	1	1															
7											2	3	6	4																	
8														4	3																
9															1																
10																		1				1									
11																	1		2												
12																				1					1						
13																				1		1	3	3	1	1				1	
14																						2	1	3	3	3	2	1			
15																							1	1	5	1	2	2	3	3	1
n	23	120	21	12	1	1	1	1	1	7	7	6	10	11	5	1	1	1	2	2	-	4	5	7	10	5	4	3	3	4	1
x̄	0,85	1	2	2	2	3	4	4	5	5,1	5,9	6,2	6,6	7,1	7,8	6	11	10	11	12,5	-	12,8	13,6	13,7	14,2	14,0	14,5	14,7	15	14,5	15

Tab. 3: The growth of *P. monti* in daily time intervals

Length mm \ days	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
0.1																							
0.2																							
0.3																							
0.4																							
0.5																							
0.6																							
0.7					1																		
0.8																							
0.9							2																
1.0								4	1														
1.1								1	4	1	1												
1.2											1		3	2	6								
1.3															1	3	1	1					
1.4																4	5		1				
1.5																	2	2	5	2			
1.6																			2	1	4	1	
1.7																				1	3	2	2
1.8																					1		2
1.9																							
2.0																							
2.1																							
2.2																							
2.3																							
2.4																							
2.5																							
2.6																							
Σ					1		2	5	5	1	2		3	2	7	7	8	3	8	4	8	3	4
$\bar{x}$					0.7		0.9	1.02	1.08	1.1	1.15		1.2	1.2	1.21	1.36	1.47	1.43	1.51	1.58	1.66	1.67	1.75

Length mm \ days	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	Σ
0.1																							
0.2																							
0.3																							
0.4																							
0.5																							
0.6																							
0.7																							1
0.8																							
0.9																							2
1.0																							5
1.1																							7
1.2																							12
1.3																							6
1.4																							10
1.5																							11
1.6		1																					9
1.7	1	1																					10
1.8	2	2	2	1																			10
1.9	1	2	1	3	3																		10
2.0					2	3	2	1	1	1													10
2.1					1		4	2	2			1											10
2.2							1	3	3	2	1												10
2.3					2	1		3			3	1											10
2.4										1	1	2	2	2	1		1						10
2.5							1									1		2		1	1	2	8
2.6																	3		3				6
Σ	4	6	3	4	8	4	8	9	6	4	4	4	2	2	1	1	4	2	3	1	1	2	156
$\bar{x}$	1.80	1.78	1.83	1.87	2.3	2.07	2.14	2.19	2.13	2.2	2.88	2.3	2.4	2.4	2.4	2.5	2.55	2.5	2.6	2.5	2.5	2.5	

Tab. 4: The growth of *Plagioscion squamosissimus* in daily time intervals

L (cm) \ T (days)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
0,1																																				
0,2																																				
0,3																																				
0,4																																				
0,5							5	5																												
0,6								2	3	4	1																									
0,7									1	3	4	1	1																							
0,8											6	3	4																							
0,9												8																								
1,0													6	8	4	4																				
1,1													2	4	8	4	2																			
1,2															2	8	10																			
1,3																	4	11	6																	
1,4																		4	4	4	2															
1,5																						1	4													
1,6																																				
1,7																												3	1							
1,8																										1	1	3	2	1						
1,9																											1		1	1		1	1			
2,0																																	2	2	1	
2,1																																	1	1	2	1
n	-	-	-	-	-	-	5	7	4	7	11	12	13	12	14	16	16	15	10	4	2	1	4	-	-	1	2	6	4	2	-	1	4	3	3	1
$\bar{x}$	-	-	-	-	-	-	0,5	0,5	0,6	0,6	0,7	0,9	0,9	1,0	1,1	1,1	1,2	1,3	1,3	1,4	1,4	1,5	1,5	-	-	1,8	1,8	1,8	1,8	1,9		1,9	2,0	2,0	2,1	2,2

P. squamosissimus

$L_t = 0.0541\ T - 0.1158$ $\qquad r^2 = 0.9630 \qquad n = 280$

$W_t = 7.1853 \cdot 10^{-5}\ T^{3.2987}$ $\qquad r^2 = 0.9732 \qquad n = 280$

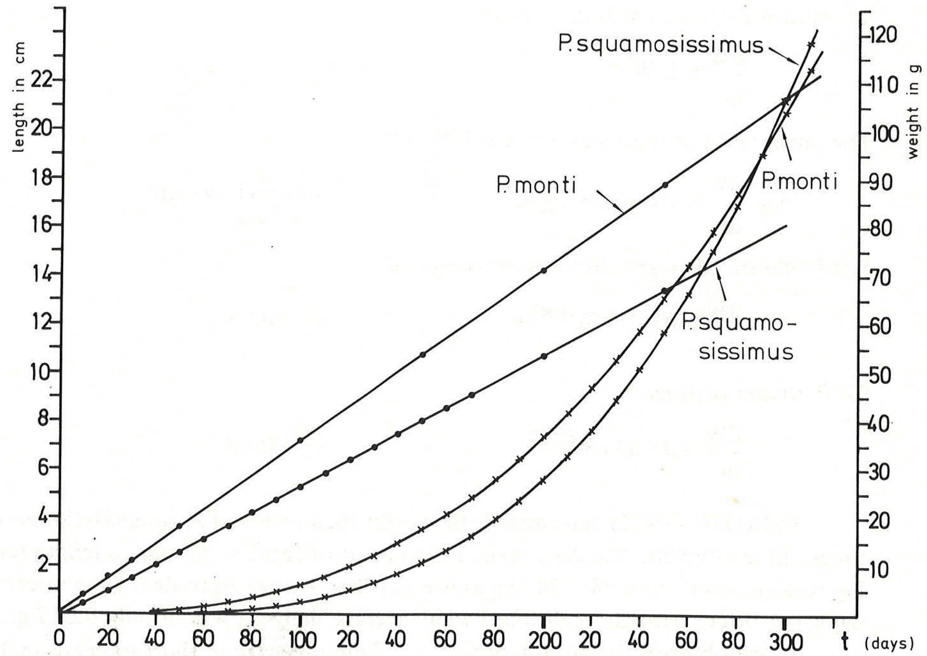

Fig. 1:
Length and weight curves of *P. monti* and *P. squamosissimus*

All functions were significantly correlated. The confidence interval for the regression coefficients in the 95 % range had the following value for the growth in length:

P. squamosissimus	± 0.0020
P. monti	± 0.0016

and the growth in weight:

P. squamosissimus	± 0.0781
P. monti	± 0.0846

The following average daily growth increments are taken from the length growth curves:

0.7 mm for *P. monti* and
0.5 mm for *P. squamosissimus*

PEIXOTO (1953) found a daily length increment of 1.15 mm for juvenile *P. squamosissimus* held and fed in tanks. After 100 days, these fish had already reached a length of 12 cm, having grown much faster than those living in natural conditions (5 - 6 cm after 100 days).

P. monti grows somewhat faster than *P. squamosissimus*; its "initial weight" of 0.1263 g is also greater than that of *P. squamosissimus* being -0.1158 g (see Fig. 1). Because the weight increases exponentially, the equation from PARKER and LARKIN (1959) and PALOHEIMO and DICKIE (1965, 1966) cited in HEPHER (1978) was used for the calculation of the daily growth increments:

$$\frac{dW}{dt} = K\,W^{x}$$

The linear form of this equation is as follows:

$$\log \frac{dW}{dt} = x \log W + \log K \qquad \begin{array}{l} W = \text{body weight} \\ t\ = \text{time} \end{array}$$

For *P. monti*, the regression was calculated as:

$$\frac{dW}{dt} = 0.0317\,W^{0.82} \qquad r^2 = 0.93$$

for *P. squamosissimus*:

$$\frac{dW}{dt} = 0.0634\,W^{0.74} \qquad r^2 = 0.99$$

PEIXOTO (1953) determined the weight increments of *P. squamosissimus* only over longer time intervals. The daily weight increment of fish 28 - 86 mm in length (corresponding to an interval from 24. - 74. days) was 0.108 g. For an equivalent time interval of 50 days, fish under natural conditions had an average daily growth of only 0.017 g.

If one observes the growth of fish < 2.5 cm in length in short intervals of 1 day (see Fig. 2, 3), one can see that the growth does not run continually, but rather is interrupted in regular intervals. In the case of *P. monti*, these growth interruptions occur every 14 days, being correlated with the lunar cycle (Fig. 2). The growth stagnates at full and new moon. This phenomenon cannot yet be explained. The first interruption took place on 5. - 7. September, 35 - 37 days previous to the catch date (11.10.78), and corresponded to the new lunar phase on 2. September. The third period of slow growth was between 29.09. and 2.10., new moon being on 2. October.

In contrast to *P. monti*, *P. squamosissimus* showed monthly growth interruptions. The fish caught on 17.11.79 (new moon being on 19.11.79) showed their first growth interruption (Fig. 3) 28 - 30 days previous thereto, at new moon on 21.10.79.

No further stagnations could be determined for both species, because with larger fish growth scattering covered the interruptions.

All the fish examined for daily rings were of marine origin (PANELLA 1973, BINGEL 1975, STRUHSAKER and UCHIYAMA 1976) and all showed growth interruptions in 14-day intervals, in most cases proved to be tide-dependent. The influence of the lunar cycle on the formation of daily rings on shells or chambers is also known from fossil and recent marine molluscs (Bivalves and Cephalopods) – PANELLA and McCLINTOCK

1968, WEST 1978). According to my knowledge, the first fresh water fish examined in this respect were *P. squamosissimus* and *P. monti.*

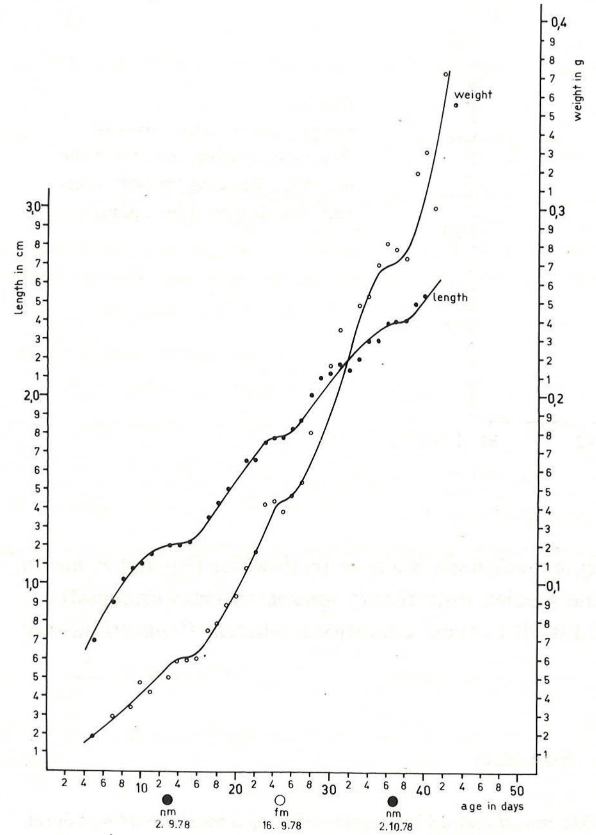

Fig. 2:
Length and weight growth curves of *P. monti* in daily time intervals, showing growth interruptions at new moon (nm) and full moon (fm) phases

From these, *P. monti* shows 14-day and *P. squamosissimus* monthly lunear periodical growth interruptions. In fresh water, the tidal cycle cannot be the cause of growth stagnations, however monthly fluctuations of the moon light intensity could be possible. The latter is presumed by KENNEDY and PEARSE (1975) on their studies of the sea urchin *Centrostephanus coronatus.*

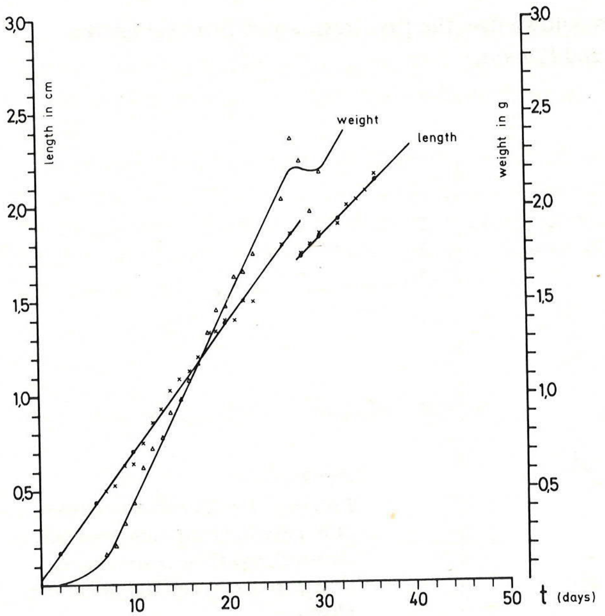

Fig. 3:
Length and weight curves of *P. squamosissimus* in daily time intervals, showing growth interruptions at new moon phases

This could mean that either *P. squamosissimus* is a pure fresh water fish and *P. monti* a marine species or that both are marine species, only that *P. squamosissimus* immigrated earlier into fresh water and has adapted itself to these conditions, whereas *P. monti* has not yet succeeded in doing so.

Summary

The age of 370 specimen of *Plagioscion monti* and 280 specimen of *P. squamosissimus* was determined by means of daily rings on the otoliths. The length of the fish were in the range of 0.4 - 15 cm. Within this size interval, the increase in length can be assumed to be linear, and the increase of weight to be an exponential function.
The function for increase in length of *P. monti* was

$$L_t = 0.0707\ T + 0.1263$$

and of *P. squamosissimus*

$$L_t = 0.0541\ T - 0.1158.$$

The increase of weight can be calculated as

$W_t = 7.1656 \cdot 10^{-5}\ T^{2.5552}$ for *P. monti* and

$W_t = 7.1853 \cdot 10^{-5}\ T^{3.2987}$ for *P. squamosissimus*

The daily weight increments of *P. monti* were calculated as

$$\frac{dW}{dt} = 0.0317\ W^{0.82}$$

and for *P. squamosissimus*

$$\frac{dW}{dt} = 0.0634\ W^{0.74}.$$

Growth is not continuous, but is interrupted periodically in relation with the phases of the moon.

Zusammenfassung

Das Alter von 370 *Plagioscion monti* und 280 *P. squamosissimus* wurde anhand von Tagesringen auf den Otolithen bestimmt. Die Länge der Fische betrug 0,4 - 15 cm. In diesem Bereich kann das Längenwachstum geradlinig, das Gewichtswachstum als Exponentialfunktion angenommen werden. Es ergaben sich als Funktionen für das Längenwachstum von *P. monti*

$$L_t = 0{,}0707\ T + 0{,}1263$$

und für *P. squamosissimus*

$$L_t = 0{,}0541\ T - 0{,}1158.$$

Das Gewichtswachstum kann aus

$W_t = 7{,}1656 \cdot 10^{-5}\ T^{2{,}5552}$ für *P. monti* und

$W_t = 7{,}1853 \cdot 10^{-5}\ T^{3{,}2987}$ für *P. squamosissimus*

berechnet werden. Die tägliche Gewichtszunahme wurde nach der Formel

$\frac{dW}{dt} = 0{,}0317\ W^{0{,}82}$ für *P. monti* und von *P. squamosissimus* nach

$\frac{dW}{dt} = 0{,}0634\ W^{0{,}74}$ berechnet.

Das Wachstum verläuft nicht kontinuierlich, sondern es werden mondabhängig Wachstumspausen eingelegt.

Resumo

A idade de 370 especimens de *Plagioscion monti* e 280 especimens de *P. squamosissimus* foi determinado atraves de aneis diarios presentes nos otólitos. Os comprimentos padrão dos peixes examinados variam de 0,4 - 15 cm. Dentro deste intervalo de tamanho o aumento de comprimento pode ser considerado linear enquanto o aumento do peso uma função exponencial. A função para o aumento de comprimento de *P. monti* dei

$$L_t = 0{,}0707\ T + 0{,}1263$$

e para *P. squamosissimus*

$$L_t = 0{,}0541\ T - 0{,}1158.$$

O aumento de peso pode ser calculado de

$W_t = 7{,}1656 \cdot 10^{-5}\ T^{2{,}5552}$ para *P. monti* e

$W_t = 7{,}1853 \cdot 10^{-5}\ T^{3{,}2987}$ para *P. squamosissimus.*

O incremento diario do peso de *P. monti* foi calculado atraves da formula

$$\frac{dW}{dt} = 0{,}0317\ W^{0{,}82}$$

e de *P. squamosissimus*

$$\frac{dW}{dt} = 0{,}0634\ W^{0{,}74}$$

O crescimento não é continuo mas periodicamente interrompido em relação das fases da lua.

References

BINGEL, F. (1972): Zur Interpretation von Otolithenstrukturen des Dorsches (*Gadus morhua* L.).- Dipl. thesis, Kiel.

HEPHER, B. (1978): Ecological aspects of warm water fishpond management.- In: GERKING, S. D. (ed.), Oxford, Blackwell Sci. Publ., 453 - 455.

KENNEDY, B. and J. S. PEARSE (1975): Lunar synchronization of the monthly reproductive rhythm in the Sea Urchin (*Centrostephanus coronatus*).- J. Exp. Mar. Biol. Ecol. 17 (3): 223 - 231.

NOMURA, H. (1976): Idade e crescimento da Pescada-do-Piaui, *Plagioscion squamosissimus* (HECKEL), do açude Amanarí (Maranguape, Ceará).- Revista Ceres 23 (127): 191 - 197.

PALOHEIMO, J. E. and L. M. DICKIE (1965): Food and growth of fishes. I. A growth curve derived from experimental data.- J. Fish. Res. Bd. Canada 22 (2): 521 - 542.

PALOHEIMO, J. E. and L. M. DICKIE (1966): Food and growth of fishes. III. Relations among food, body size and growth efficiency.- J. Fish. Res. Bd. Canada 23 (8): 1209 - 1248.

PANELLA, G. (1971): Fish otoliths: daily growth layers and periodical patterns.- Science N. Y. 173: 1124.

PANELLA, G. (1974): Otolith growth patterns: an aid in age determination in temperate and tropical fishes.- In: T. B. BAGENAL (ed.).The ageing of fish, 28 - 39, Union Brothers, Surrey.

PANELLA, G. and C. MAC CLINTOCK (1968): Biological and environmental rhythms reflected in molluscan shell growth.- J. Palaeont. 42 (5), (suppl.): 64 - 80.

PARKER, R. R. and P. A. LARKIN (1959): Concept of growth in fishes.- J. Fish. Res. Bd. Canada 16: 721 - 745.

PEIXOTO, J. T. (1953): Contribuição para o estudo do crescimento de corvina *Plagioscion squamosissimus* (HECKEL) en cativeiro (Actinopterygii, Sciaenidae).- Rev. Brasil. Biol. 18 (2): 173 - 177.

RAUCK, G. (1976): A technique of sawing thin slides out of otoliths.- Ber. dt. wiss. Kommn. Meeresforsch. 24: 339 - 341.

SILVA, S. L. O. e R. S. DE MENEZES (1950): Alimentação de corvina *Plagioscion squamosissimus* (HECKEL) da Lagoa de Nazaré, Piauí (Actinopterygii, Sciaenidae).- Rev. Bras. Biol. Rio de Janeiro 20 (2): 257 - 264.

SOARES, L. H. (1978): Revisão taxonomica dos Sciaenideos de àgua doce da região amazonica Brasileira (Osteichthyes, Perciformes, Sciaenidae).- M. Sc. thesis, Manaus, Brasil.

STRUHSAKER, P. and J. H. UCHIYAMA (1976): Age and growth of the Nehu, *Stolephorus purpureus* (Pisces, Engraulidae) from the Hawaiian Islands as indicated by daily growth increments of sagittae.- Fish. Bull. 74: 9 - 17.

WEST, S. (1978): Moon history.- Science News 114: 25.

WORTHMANN, H. (1980): The early growth stages of the pescada (*Plagioscion monti* SOARES).- Arch. Fish. Wiss. 30 (2/3): 145 - 156.

Author's address:

Dr. Heino O. Worthmann
Turkish-German Inland Fisheries Project
Hydrobiological Research Institute
University of Istanbul
Kurtköy - Sapanca P. K. 11
Türkiye

Accepted for publication in October 1982